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Thermal Analysis of Shell And Tube Heat Exchanger Using Corrugated Tube And Corrugated Shell

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Abstract: **Corrugated shell and corrugated tube were employed instead of smooth shell and smooth tube through a shell and tube heat exchanger in this Paper. Distinct arrangements of concave and convex type of corrugated tubes were investigated. Previous studies have focused on only thermal characteristics of corrugated tubes. Hence, in the present work heat transfer coefficient is studied for a shell and tube heat exchanger made of corrugated shell and corrugated tube by using software solid works and heat transfer rate is evaluated for different arrangements of corrugated tubes. Maximum heat transfer was observed for heat exchanger made of convex corrugated tube and concave corrugated shell.**

This paper mainly focuses on improving the heat transfer capability in a shell and tube heat exchanger by varying tubes geometry using solid works. Study carried out on the design of the heat exchanger and by increasing diametrical ratio to prove more heat transfer is possible.

NOMENCLATURE

s ---- Specific entropy, J/kg. K

T---- Temperature, K

U---- Overall heat transfer coefficient, (W/m2K)

h---- Specific enthalpy, J/kg. K

k---- Thermal conductivity, W/m 0C

Cp-- Specific heat, J/kgK

D--- Diameter, mm

Re--- Reynolds number

T_{ho}--- hot water outlet temperature

T_{hi}--hot water inlet temperature

T_{co}-- cold water outlet temperature

T_{ci}-- cold water inlet temperature

I. INTRODUCTION

One of the important processes in engineering is the heat exchange between flowing fluids, and many types of heat exchangers are employed in various types of installations, as petrol-chemical plants, process industries, pressurized water reactor power plants, nuclear power stations, building heating, ventilating, and air-conditioning and refrigeration systems. As far as construction design is concerned, the tubular or shell and tube type heat exchangers are widely in use.

The shell-and-tube heat exchangers are still the most common type in use. They have larger heat transfer surface area-to-volume ratios than the most of common types of heat exchangers, and they are manufactured easily for a large variety of sizes and flow configurations. They can operate at high pressures, and their construction facilitates disassembly for periodic maintenance and cleaning. The shell-and-tube heat exchangers consist of a bundle of tubes enclosed within a cylindrical shell. One fluid flows through the tubes and a second fluid flows within the space between the tubes and the shell. Geometry is one of the parameter which effects the performance of heat exchanger.Hence by modifying geometry the flow in geometry is also verified by Rossi et 3 al. [1] performed a comparison between smooth and helically corrugated wall tubes in a shell and tube heat exchanger. They observed that in the fully developed turbulent flow regime a moderate overall heat transfer enhancement can be achieved. Barba et al. [5] presented the experimental results of heat transfer and pressure drop in corrugated tube, which is used in the chemical and food industries.

However also few of them also studied the thermal characteristics by using corrugated tubes, but by the use of heat exchanger by corrugating shell as well as corrugating tube more heat transfer can be achieved. Solid works can provide the flexibility to construct computational models that are easily adapted to a wide variety of physical conditions without constructing a large-scale prototype or expensive test rigs. Therefore, Solid works can provide an effective platform where various design options can be tested and an optimal design can be determined

Heat Exchanger: Heat exchangers are devices used to transfer heat between two or more fluid streams at different temperatures. Heat exchangers find widespread use in power generation, chemical processing, electronics cooling, air-conditioning, refrigeration, and automotive applications. In this chapter we will examine the basic theory of heat exchangers and consider many applications. In addition, we will examine various aspects of heat exchanger design and analysis.

Heat Exchanger Classification

Due to the large number of heat exchanger configurations, a classification system was devised based upon the basic operation, construction, heat transfer, and flow arrangements. The following classification as outlined by Kakac and Liu (1998) will be discussed:

• Recuperators and regenerators

• Transfer processes: direct contact or indirect contact

• Geometry of construction: tubes, plates, and extended surfaces

• Heat transfer mechanisms: single phase or two phase flow

• Flow Arrangement: parallel flow, counter flow, or cross flow

The four main types of heat exchangers by comparing their application, capacity and range of duty which are classified based on the flow pattern of fluid in them are:

Corrugated Tubular Heat Exchangers (CTHE)

Corrugated Tube Heat Exchangers are shell and tube heat exchangers which use corrugated tubes instead of plain tubes.Corrugated Tubes take the best features of both the plain tube and the plate heat exchanger.Corrugated tube is produced by indenting a plain tube with a spiral pattern.

- Plain tubes offer the best geometry to withstand pressure but the worst for heat transfer due to rapid build-up of boundary layer.
- Plates in a plate heat exchanger induce local turbulence to increase heat transfer coefficient but is limiting in terms of operating pressures and temperatures due to elastomer gaskets. Also, the relatively narrow gap limits its use to fluids without large fibres and particulates.

By choosing the depth, angle and width of the indentation carefully, the rate of decrease in boundary layer resistance can exceed the rate of increase in pressure loss.

Why were Corrugated Tubes Developed ?

• To increase tube side heat transfer coefficients, with minimum increase in pressure loss.

• To overcome disadvantages of other methods of artificial enhancing the heat transfer coefficient, viz., Increased resistance to fluid flow – increased pressure loss.

Unpredictable characteristics difficult to design / manufacture / replace / service.

Difficult to clean. Low running reliability

• To have efficient heat transfer even in liquids with high viscosity, liquids with large fibres or particulates.

The Technology:

Corrugated Tubes were developed to incorporate best features of both the plain tube and the plate heat exchanger.Corrugated tube is produced by indenting a plain tube with a spiral pattern. Between the helical impressions, around the circumference of the tube, secondary flow, typically in the form of eddies occur. Increase in heat transfer coefficient brings the temperature of the tube wall closer to the temperature of the bulk fluid on the tube. The roughness elements need to have a minimum height so as to influence the flow and thus the heat transfer.

Models:

Corrugated Tube Heat Exchangers are produced in four configurations.

- B-type Series : Multi-tube for Industrial use
- Multi-tube Series : for food industry and pharmaceutical use
- Mono-tube : for fluids containing particles and/or fibres
- Triple-tube Series: for aseptic applications

II. LITERATURE SURVEY

The Experimental exergy analysis for shell andtube device manufactured from furrowed shell and furrowed tube and determined the quantity of warmth transfer units occurred and calculated the exergy losses [1]

- A comparison between sleek and helically furrowed wall tubes in a very shell and tube device and that they determined that within the absolutely developed flow regime a moderate overall heat transfer improvement is achieved [2]
- The effects of corrugation pitch on the condensation heat transfer and pressure drop of R-134 within horizontal furrowed tube was by experimentation studied and their findings incontestable higher heat transfer constant and pressure drop of furrowed tube as compared with the sleek tube for all the experimental conditions. [3]
- The studies allotted for the turbulent heat transfer improvement in a very device victimization helically furrowed tube. They used the furrowed tube because the tube of the double pipe device. Their findings showed that the Nusselt range and friction issue ar three.01 and 2.14 times higher than the sleek tube [4]

OUTER CONCAVE INNER CONCAVE:

Table : Outer Concave Inner Concave Maximum Minimum Parameters

Name	Minimum	Maximum
Pressure [Pa]	101193.53	102022.12
Temperature [K]	295.00	323.00
Density (Fluid) [kg/m^3]	987.52	997.11
Velocity [m/s]	0	0.779
Velocity (X) [m/s]	-0.595	0.779
Velocity (Y) [m/s]	-0.532	0.720
Velocity (Z) [m/s]	-0.508	0.507
Temperature (Fluid) [K]	295.00	323.00
Temperature (Solid) [K]	297.67	321.02
Density (Solid) [kg/m^3]	7900.00	7900.00
Vorticity [1/s]	0.004	107.195
Shear Stress [Pa]	0	4.22
Relative Pressure [Pa]	-131.47	697.12
Heat Transfer Coefficient [W/m^2/K]	6.453e-008	823.789
Surface Heat Flux [W/m^2]	-73712.808	65603.003
Heat Flux [W/m^2]	1.670e-004	1346657.485
Wall Temperature [K]	295.00	321.02
Overheat above Melting Temperature [K]	-1378.150	-1352.134
Turbulence Length [m]	6.742e-006	0.009
Turbulence Intensity [%]	0.68	1000.00
Turbulent Energy [J/kg]	1.048e-006	0.039
Turbulent Dissipation [W/kg]	1.07e-005	1.23

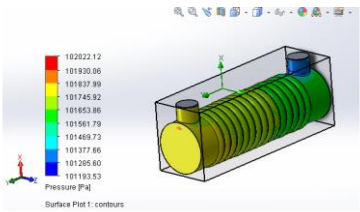


Figure Pressure distribution in Outer Concave Inner Concave

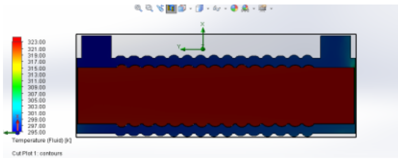


Figure Cut plot Temperature Distribution of fluid in section plane Outer Concave Inner Concave .

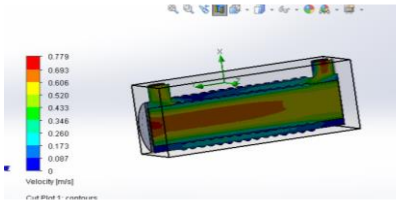
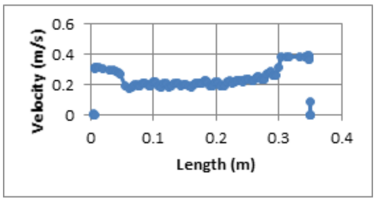


Figure Outer Concave Inner Concave Velocity Profile



Graph Velocity of the Fluid Inlet to outleT

INNER CONVEX OUTER CONVEX

Table Min/Max parameters for Outer Convex Inner Convex

Name	Minimum	Maximum
Pressure [Pa]	101215.86	102002.52
Temperature [K]	295.00	323.00
Density (Fluid) [kg/m^3]	987.52	997.11
Velocity [m/s]	0	0.794
Velocity (X) [m/s]	-0.561	0.571
Velocity (Y) [m/s]	-0.794	0.574
Velocity (Z) [m/s]	-0.594	0.753
Temperature (Fluid) [K]	295.00	323.00
Temperature (Solid) [K]	295.00	319.48
Density (Solid) [kg/m^3]	7900.00	7900.00
Vorticity [1/s]	8.142e-004	173.974
Shear Stress [Pa]	0	8.05
Relative Pressure [Pa]	-109.14	677.52
Heat Transfer Coefficient [W/m^2/K]	3.035e-006	8500.626
Surface Heat Flux [W/m^2]	-55797.296	67123.578
Heat Flux [W/m^2]	3.528e-004	4820645.153
Wall Temperature	295.00	319.48

[K]		
Overheat above Melting Temperature [K]	-1378.150	-1353.674
Turbulent Viscosity [Pa*s]	3.4590e-009	0.2098
Turbulence Length [m]	7.619e-006	0.010
Turbulence Intensity [%]	1.49	1000.00
Turbulent Energy [J/kg]	2.299e-008	0.049
Turbulent Dissipation [W/kg]	8.12e-010	2.37

CONTOURS:

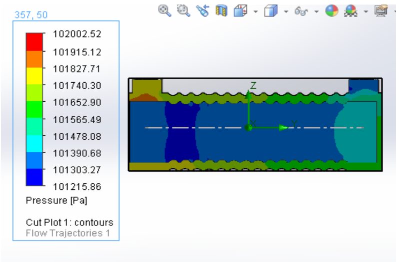


Figure Pressure distribution over Outer Convex Inner Convex

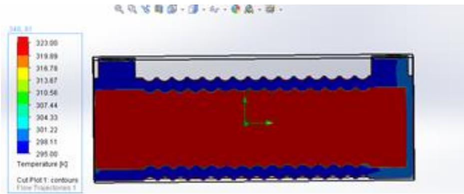


Figure Cut plot Temperature Distribution of fluid in section plane Outer Convex Inner Convex

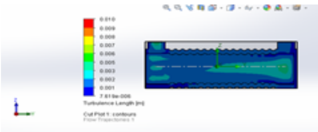
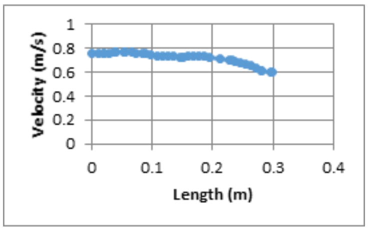
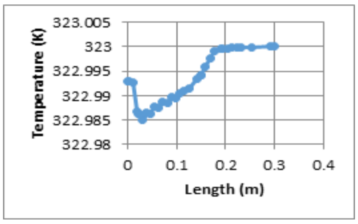


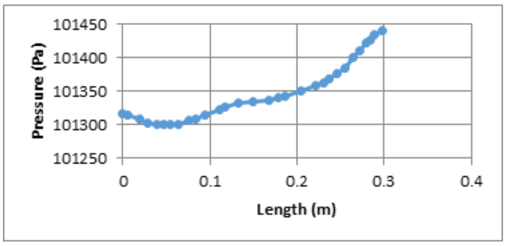
Figure outer convex inner convex velocity profiles



Graph Velocity along the length



Graph Temperature along length



Graph Pressure along length

Inner smooth outer smooth

TABLE Outer Smooth Inner Smooth Maximum Minimum Parameters

Min/Max Table

Name	Minimum	Maximum
Pressure [Pa]	101219.68	101766.97
Temperature [K]	293.20	323.00
Density (Fluid) [kg/m^3]	987.52	997.42
Velocity [m/s]	0	0.767
Velocity (X) [m/s]	-0.593	0.604
Velocity (Y) [m/s]	-0.584	0.533
Velocity (Z) [m/s]	-0.598	0.763
Temperature (Fluid) [K]	293.20	323.00
Temperature (Solid) [K]	293.95	321.15
Density (Solid) [kg/m^3]	7900.00	7900.00
Vorticity [1/s]	0.031	115.637
Shear Stress [Pa]	0	5.21
Relative Pressure [Pa]	-105.32	441.97
Heat Transfer Coefficient [W/m^2/K]	8.276e-006	4744.702
Surface Heat Flux [W/m^2]	-48459.294	49463.443
Heat Flux [W/m^2]	6.029e-005	82998.772
Wall Temperature [K]	293.95	321.15
Overheat above Melting Temperature [K]	-1379.203	-1352.000
Turbulence Length [m]	7.204e-006	0.009
Turbulence Intensity [%]	1.09	1000.00
Turbulent Energy [J/kg]	8.784e-008	0.023
Turbulent Dissipation [W/kg]	4.28e-008	0.60

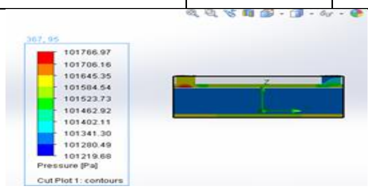


Figure Pressure Cut plot for Outer Smooth Inner Smooth.

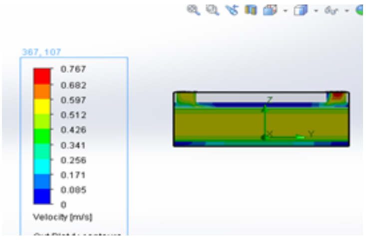


Figure Velocity Cut plot for Outer Smooth Inner Smooth due to no change in structure

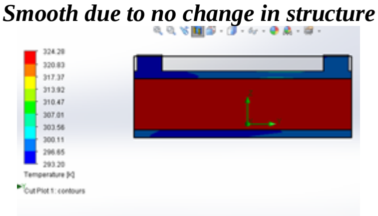
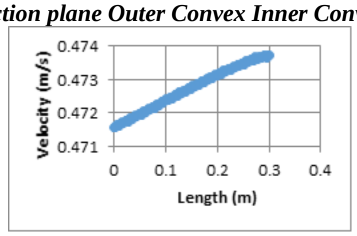
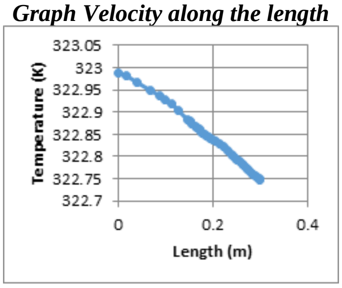


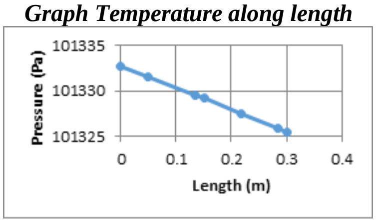
Figure Cut plot Temperature Distribution of fluid in section plane Outer Convex Inner Convex



Graph Velocity along the length



Graph Temperature along length



Graph Pressure along length

Outer smooth Inner concave

Table Outer Smooth Inner Concave Maximum Minimum Parameters

Min/Max Table

Name	Minimum	Maximum
Pressure [Pa]	101203.66	101794.97
Temperature [K]	293.20	323.00
Density (Fluid) [kg/m^3]	987.52	997.56
Velocity [m/s]	0	0.736
Velocity (X) [m/s]	-0.481	0.483
Velocity (Y) [m/s]	-0.718	0.452
Velocity (Z) [m/s]	-0.598	0.735
Temperature (Fluid) [K]	293.20	323.00
Temperature (Solid) [K]	293.20	321.82
Density (Solid) [kg/m^3]	7900.00	7900.00
Vorticity [1/s]	0.005	101.678
Shear Stress [Pa]	0	5.03
Relative Pressure [Pa]	-121.34	469.97
Heat Transfer Coefficient [W/m^2/K]	0.002	10736.178
Surface Heat Flux [W/m^2]	-93366.325	81089.240
Heat Flux [W/m^2]	8.227e-006	768437.725
Wall Temperature [K]	293.20	321.82
Overheat above Melting Temperature [K]	-1379.950	-1351.325
Turbulent Viscosity [Pa*s]	8.1500e-010	0.1824
Turbulence Length [m]	7.908e-006	0.009
Turbulence Intensity [%]	0.55	1000.00
Turbulent Energy [J/kg]	4.931e-010	0.024
Turbulent Dissipation [W/kg]	2.48e-012	0.63

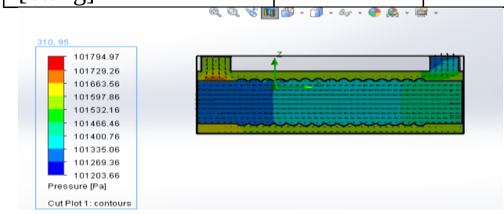


Figure Pressure Cut plot for Outer Smooth Inner concave

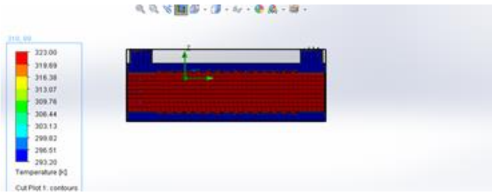


Figure Cut plot Temperature Distribution of fluid in section plane Outer smooth Inner Concave

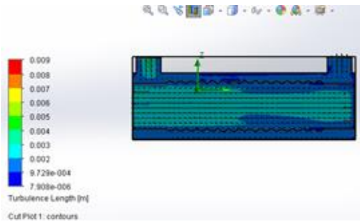
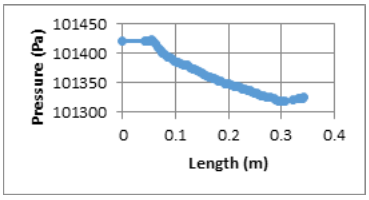


Figure outer smooth inner concave velocity profiles



Graph Pressure along length

Outer smooth Inner convex

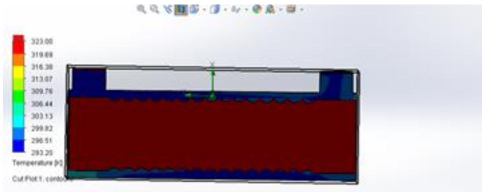


Figure Cut plot Temperature Distribution of fluid in section planeOuter smooth Inner Convex

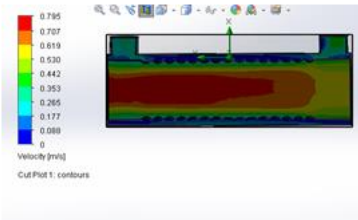
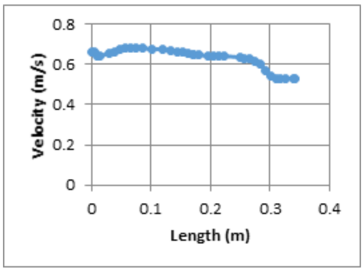
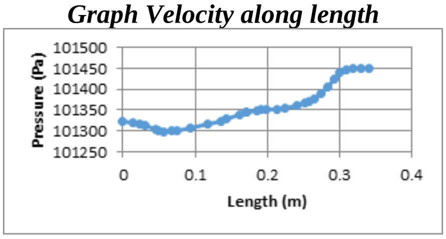


Figure Velocity Cut plot for Outer Smooth Inner convex.



Graph Velocity along length



Graph Pressure distribution along the model

INNER CONVEX OUTER CONCAVE

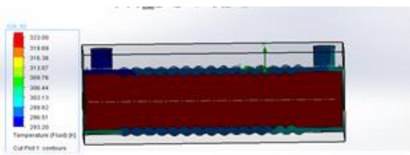
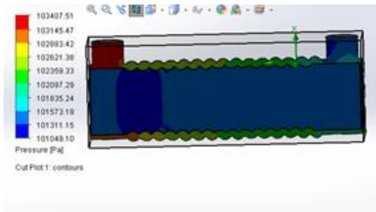


Figure Cut plot Temperature Distribution of fluid in section planeOuter smooth Inner Convex



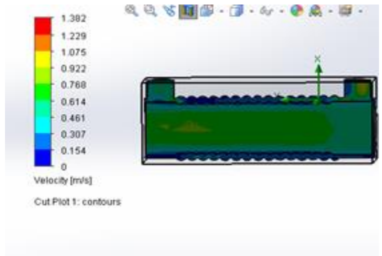
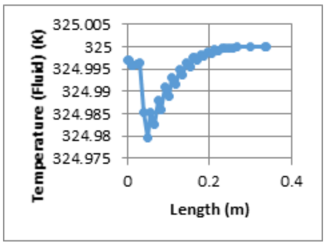
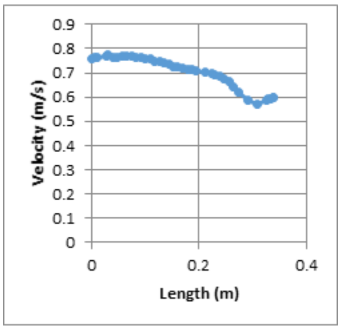


Figure outer concave inner convex velocity profiles



Graph Temperature along length



Graph Velocity along length

The above Graph represents Length along the x-axis and velocity in y axis We can see the change in velocity from the graph

III. CONCLUSION

Various arrangements of convex and concave corrugated tubes were studied. The key findings are summarized as follows:

The results of solid works are approximate to the experimental values so it is consideredable to do the analysis in solid works and the analysis is done by changing the diametrical ratio for various arrangements of corrugated shell and corrugated tubes in shell and tube heat exchanger.

By comparing results of various arrangements of shell and tube heat exchangers made corrugated shell and corrugated tube, it is clearly concluded that average heat transfer coefficient, heat transfer rate and NTU are increased. This is because as the surface area increases due to the use of corrugated tubes and also by improving diametrical ratio.

Maximum heat transfer coefficient was obtained for heat exchanger made of concave corrugated shell and convex corrugated tube.

IV. FUTURE SCOPE

Here in this project, the analysis is carried out in the SOLID WORKS software for various geometries by using water as fluid in inner tube and outer shell. If we use nano fluids instead of water further the heat transfer rate may increase more.

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